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EFFECTS OF A PROLONGED REDUCTION IN DIET ON 25 MEN

*I. INFLUENCE ON BASAL METABOLISM AND NITROGEN
EXCRETION*

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Read before the Academy, April 22, 1918

A year ago, realizing that this nation faced a food shortage, several members of the staff of the Nutrition Laboratory decided that positive evidence regarding the effect of a prolonged restriction in diet would give knowledge of possible use in an imminent emergency. Such data seemed especially important as exact experimentation on a large number of men and women, including many with peculiar dietetic habits and a supposedly low metabolism, had failed to indicate that the basal or maintenance metabolism of any particular class of persons or, indeed, of any single individual (making due allowance for differences in weight), is materially lower in energy requirement than the basal metabolism of the average individual. Since the law of the conservation of energy obtains in the human organism, it is clear that with uniform maintenance metabolism, the food requirement must also be fairly uniform. On the other hand, no evidence is available as to the actual effect of a reduction in diet, continued over a considerable period of time. Accordingly, a research was carried out by the Nutrition Laboratory during the past winter in which the effect of a low diet upon a group of normal adults was studied for a period of several months.

If the food intake is reduced below the maintenance level and the basal requirement remains constant, it is plain that there must be drafts upon previously-stored body reserves. In any study of the effect of a reduced diet, since we are dealing primarily with the question of energy rather than with a specific ingredient of the food, there must be the strictest control of the diet, so that the exact intake of energy over relatively long periods may be known. This involves, with human subjects, a degree of personal integrity and veracity that cannot be assumed but must be demonstrated.

For subjects we selected 12 young men from a considerable number of volunteers from the student body of the International Y. M. C. A. College in Springfield, Mass. The average age of the men was twenty-three years. For a period of four months these men were kept upon a much restricted diet, with an energy content of approximately one-half to two-thirds of their caloric requirements prior to the test. During the first few weeks there was a distinct drop in body weight. When the body weight had fallen on the average 12%, the calories in the diet were increased so as to prevent further loss in weight. The measurement of the caloric consumption at this sustained weight level would indicate the true caloric requirement for maintenance. For control 12 men from the same student body, living under exactly the same conditions save for the dietetic restrictions, were likewise studied and their food intake occasionally measured for periods of four or five days.

It was impossible to place all the men in respiration chambers and study their metabolism during the entire twenty-four hours, for it was realized that these men were, first, college students, and second, volunteers for scientific experimentation, and that their college duties, both intellectual and physical, must be carried out; hence they were all cautioned at the beginning of the study not to restrict their activities in any way. Even with the best conditions it could not be assumed that the muscular activity of both groups of men would be exactly alike throughout the period of observation. It thus seemed best to make the measurements of the metabolism upon a uniform basis, excluding uncertain and, more particularly, uneven muscular activity. For this purpose all of the first group of men were studied during periods of complete muscular repose and without food in the stomach, so as to obtain the basal metabolism practically every morning from the 27th of September, 1917, to the 3rd of February, 1918. The individual measurements were controlled by a group study with a large respiration chamber in the Nutrition Laboratory in which the 12 men slept every alternate Saturday night; the metabolism during deep sleep was thus obtained. No individual tests were made with the control squad, but group measurements were obtained on the alternate Saturday nights and used for comparison with the group results obtained for the diet squad.

Prior to the dietetic restriction, the basal metabolism, measured inside the large respiration chamber at night, was the same with the first and second squads, thus giving admirable proof that a group of 12 men was sufficiently large for our purpose. In addition to the observations on weight and basal metabolism, records were obtained of the total nitrogen in the food, feces, and urine during the entire four months, frequent observations were made of the pulse and respiration rate, total ventilation of the lungs, alveolar carbon dioxide, energy requirement for walking a definite distance at a definite speed, the blood (including counts of the red and white corpuscles and differentials, and determination of the haemoglobin), the blood pressure and rectal and skin temperatures. Clinical examinations were also made, as

well as measurements of the body surface, strength tests, and extensive psychophysiological examinations of the neuro-muscular processes. The effects of the prolonged reduction in diet on these various functions were striking. Those dealing primarily with basal metabolism may be summed up as follows:

1. A gradual reduction in weight to a point 12% below the initial weight took place during a period of from three to ten weeks, with low calories and a moderate amount of protein in the food intake. The normal demand of the men prior to the dietetic alteration ranged from 3200 to 3600 net calories. One squad of 12 men subsisted for three weeks on 1400 net calories without special disturbance.

2. After the loss in weight of 12% had been reached, the net calories required to maintain this weight averaged about 2300, or approximately one-third less than the original amount required.

3. At the end of the reduction in weight, the actual heat output during the hours of sleep, as computed by indirect calorimetry, was approximately one-fourth less than normal, thus giving a rough confirmation of the lowered number of calories found by actual measurement of the food intake. That there was no seasonal variation in metabolism was shown by the constancy in the metabolic level of the control squad.

4. The heat output by indirect calorimetry per kilogram of body weight and per square meter of body surface was essentially 18% lower than at the beginning of the study.

5. The analyses of food, feces, and urine were sufficiently complete to permit a nitrogen balance to be made and it was found that throughout the period of loss in weight and for some time subsequent thereto, there was a marked loss of nitrogen to the body. In round numbers these men each lost approximately 150 grams of nitrogen. There is an intimate relationship between this 'surplus nitrogen' and the metabolic level. Removing what we may designate as 'surplus nitrogen,' we believe distinctly lowers the stimulus to cellular activity.

6. The nitrogen output per day at the maintenance diet of 2300 net calories was about 9 grams. A control group of 12 men, living substantially the same life and eating in the same dining room, but with unrestricted diet, showed a nitrogen output of 16 to 17 grams per day.

7. The pulse rate was astonishingly lowered. Many of the men showed morning pulse rates as low as 33 and daily counts of 32, 31, and 30 were obtained; at least one subject gave six definite counts on one morning of 29.

8. The blood pressure, both systolic and diastolic, was distinctly lowered.

9. The skin temperature, as measured on the surface of the hands and forehead, was, with some subjects, considerably lower than normal. With most of the men normal temperatures prevailed.

10. The rectal temperature was practically normal.

The general picture that the men presented at the end of the test or at their minimum weight was one of noticeable emaciation, particularly in the face,

but all the men continued the usual college activities with no obvious reduction in stamina.

Two of the men had chronic bad noses. One was operated upon during the test and the other should have been. Aside from these two, the prevalence of colds during the period was about the same as with the other college students. During the study three men underwent ether narcosis for operations (on nose, foot, and hemorrhoids) and made rapid recoveries. One man at the lowest period of weight contracted what was diagnosed by three physicians as typhoid fever, although the final course of the disease seemed to leave the diagnosis somewhat in doubt. He ran a very high fever, and was critically ill for some time, but has made a complete convalescence and recovery and has returned to college.

The most noticeable discomfort experienced by the subjects was a feeling of cold, which it is only fair to say might be due in large part to the severity of the past winter. In general, notwithstanding the very great reduction in the metabolism (which we believe was due to the removal from the body of the stimulus to cellular activity of approximately 150 grams of 'surplus nitrogen'), the whole period of lowered food intake had no untoward effect upon the physical or mental activities of these men, and they were able to continue successfully their college duties.

The control squad, having demonstrated the absence of a seasonal variation in metabolism for about three months, were put for a period of three weeks upon a restricted ration of less than one-half their previous calorie consumption. In all details the picture exhibited by the first squad was strikingly duplicated by the second squad, although, as the loss in weight was obviously not so great (6% as compared with 12%) the phenomena were quantitatively somewhat less emphasized.

The entire research will be published in conjunction with our co-workers, Drs. Walter R. Miles, and H. Monmouth Smith, in a monograph of the Carnegie Institution of Washington in the near future.

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II. BEARING ON NEURO-MUSCULAR PROCESSES AND MENTAL CONDITION

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Communicated by F. G. Benedict. Read before the Academy, April 22, 1918

It is obvious that any adequate investigation of prolonged reduction in diet must include observations of the neuro-muscular processes and general mental condition of the individuals studied. In the low-diet research the psychological measurements were made at the Nutrition Laboratory on Sat-